Stream Discharge Measurements
Current-Meter Measurements

This outline describes general features of the procedures used by the U.S. Geological Survey in making streamflow measurements. Details of various types of equipment, specific procedures for use of the meter in a variety of situations (i.e., from bridges, boats, under ice, etc.), and other re- lated matters, will be found in reference 1.

I. Midsection method of making a current meter measurement

A. General procedure

1. The cross-section at which the measurement is being made is broken into small rectangular sections.

2. The average velocity for each section is obtained from current meter readings.

3. The area of each section is calculated.

4. Discharge through each small section is computed by the formula Q = AV.

5. The sum of the discharges for each small section gives the total discharge.

B. Detailed procedure (Refer to Figure 1)

1. Cross-section is defined by depths at locations 1, 2, 3, 4...n.

2. At each location velocities are determined by current meter to obtain the mean of the vertical distribution of velocity.

a. It is assumed that this mean velocity is that existing in the corresponding partial rectangular area.

3. Depth of the "corresponding partial rectangular area" is as determined in "1" above. Width extends from half the distance from the preceding meter location to half the distance to the next meter location.

a. For example, width of partial section 4 (heavily outlined in Figure 1) is:

$$\frac{b_5 - b_4}{2} + \frac{b_4 - b_3}{2}, \quad \text{or} \quad \frac{b_5 - b_3}{2}, \text{ which is the same thing.}$$
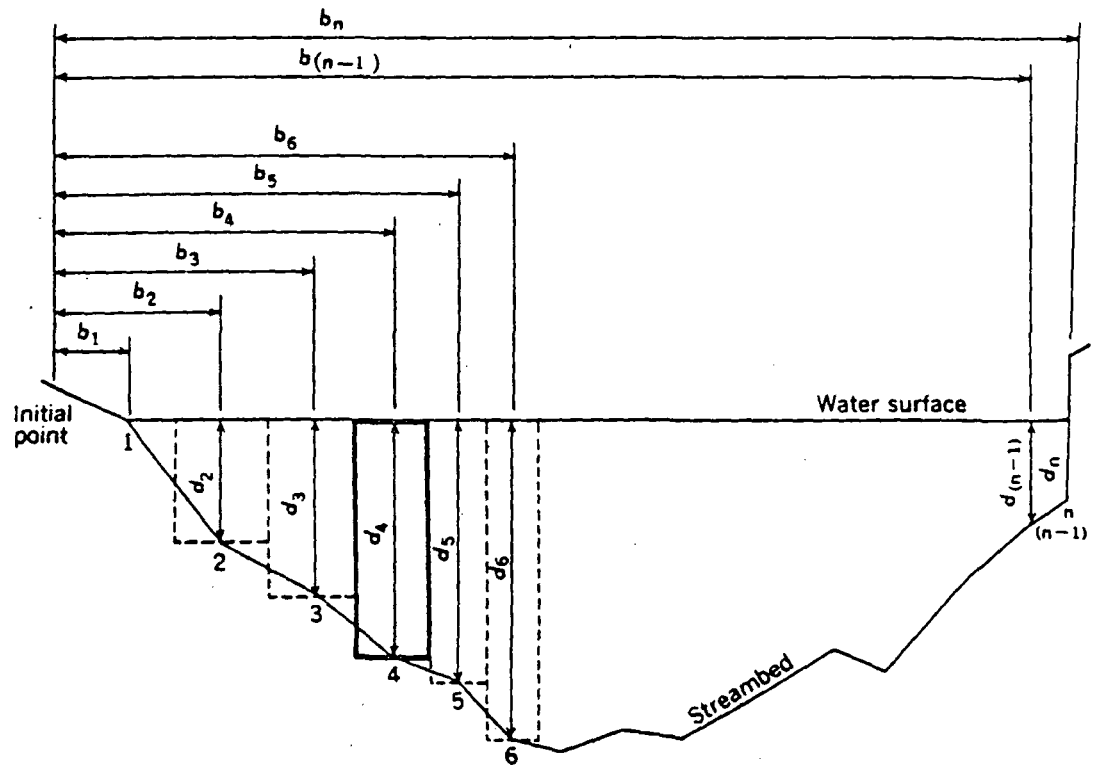
EXPLANATION

1, 2, 3, ... n	Observation points
$b_1, b_2, b_3, \ldots \ldots b_n$	Distance, in feet, from the initial point to the observation point
$d_1, d_2, d_3, \ldots \ldots d_n$	Depth of water, in feet, at the observation point
Dashed lines	Boundary of partial sections; one heavily outlined discussed in text

Figure 1.—Definition sketch of midsection method of computing cross-section area for discharge measurements.

4. Discharge through section 4 is then

$$q_4 = a_4 v_4$$

$$a_4 = \text{Depth x width} = d_4 \times \frac{b_5 - b_3}{2}$$

$$v_4 = \text{Mean velocity in vertical, as measured}$$

Then $q_4 = v_4 \left(\frac{b_5 - b_3}{2} \right) d_4$

5. A similar procedure is followed for partial sections located at the water's edge.

a. At the beginning of the cross-section (Location 1, Figure 1) the "preceding location" is considered coincident with location 1. Thus

$$q_1 = v_1 \left(\frac{b_2 - b_1}{2} \right) d_1$$

In this example, since $d = 0$, $q_1 = 0$

b. At location b_n

$$q_n = v_n \left(\frac{b_n - b_{n-1}}{2} \right) d_n$$

Here v_n may or may not be zero.

c. The above formulas are used when there is water only on one side of an observation point, such as at piers, abutments, or islands.

d. Velocity at end section is usually estimated as some percentage of that at the adjacent section, as it normally cannot be measured with the current meter.

6. After q is calculated for each partial section, the total discharge is given by

$$Q = q_1 + q_2 + q_3 + \ldots \ldots + q_n$$

II. Measurement of velocity

The current meter measures velocity at a point. The mean velocity in a vertical is desired in making discharge measurements. This mean value can be obtained by taking velocity observations at many points in the vertical. It can be approximated by making a few velocity observations and using a known relation between these and the mean in the vertical. Various methods of measuring velocity are described below.

A. Vertical-velocity curve method

  1. Velocities are measured at a series of points between the
      water surface and the stream bed, generally at 0.1 ft.
      intervals between 0.1 and 0.9 of the depth.

  2. Observations are always made at 0.2, 0.6, and 0.8 of the
      depth.

  3. Observations are made at least 0.5 foot from the water surface
      and from the stream bed with the Price AA meter, and are made
      at least 0.3 foot from these boundaries with the Price pygmy meter.

  4. Observed velocities are then plotted against depth (Figure 2).
      In order to compare curves at different verticals, depths are
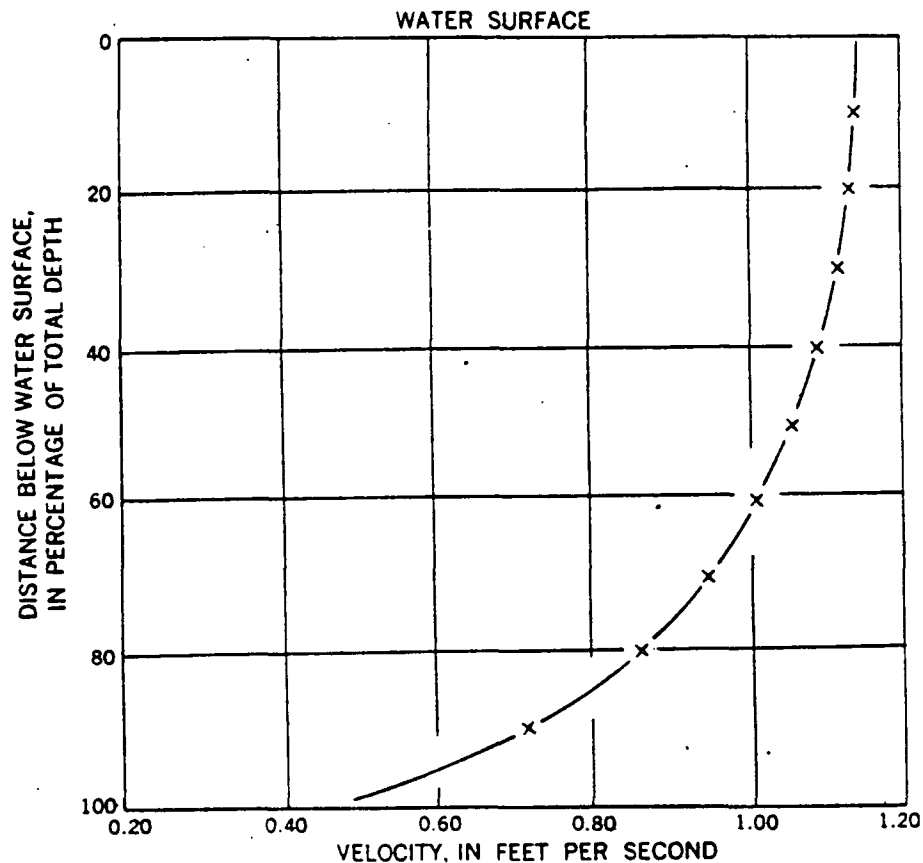   plotted as proportional parts of the total depth.

Figure 2 —Typical vertical-velocity curve.

5. The mean velocity is obtained by dividing the area under the curve by the depth.

6. This method is not generally adapted to routine discharge measurements because of the extra time required to collect field data and compute the mean velocity.

7. It is valuable for determining coefficients for application to the results obtained by other methods.

B. Two point method

1. Velocities are measured in each vertical at 0.2 and 0.8 of the depth, and the average taken as the mean in the vertical.

2. This method gives more consistent and accurate results than any other method except the vertical velocity curve method.

3. This method is not used at depths less than 2.5 feet because the meter would be too close to the water surface and the stream bed to give reliable results.

C. Six-tenth-depths method

1. One observation of velocity is made in the vertical at 0.6 depth and is taken to be the average velocity in the vertical.

2. This method gives reliable results under the following conditions:

   a. When the depth is between 0.3 foot and 2.5 feet
   b. When the velocity at 0.2 depth cannot be observed accurately
   c. When use of a sounding weight makes it impossible to place the meter at the 0.8 depth
   d. When the stage is changing rapidly and a measurement must be made quickly

D. Two-tenths-depth method

1. Velocity is observed at 0.2 depth and a coefficient applied to obtain mean in the vertical.

2. Used mainly at times of high water when velocities are great, making it impossible to obtain soundings or place the meter at the 0.8 or 0.6 depth.

3. A relation can be developed between the 0.2 depth velocity and the true mean velocity by developing vertical-velocity curves.

   a. Relation between 0.2 depth velocity and true mean velocity either remains constant or varies uniformly with stage at any measuring section.

       b. Usual coefficient to adjust 0.2 depth velocity to mean velocity is about 0.88.

    4. The two point method and the 0.6-depth method are preferred over the 0.2-depth method because of their greater accuracy.

E. Three-point method

    1. Velocities are observed at 0.2, 0.6, and 0.8 depth.

    2. Usually the average of the 0.2 and 0.8 depth velocities is then averaged with the 0.6 depth observation to obtain the mean velocity.

    3. This method used when velocities in the vertical are abnormally distributed, or when the 0.8-depth observation is made where the velocity is seriously affected by friction or turbulence.

    4. Depth must be greater than 2.5 feet for this method to be used.

III. Recording data

A. A copy of the front and back of the data sheet used by the USGS (1963 version) is shown in Figure 3.

B. A copy of a completed data sheet is shown in Figure 4. Note the following:

    1. The bank at which measurement is begun (and ended) is identified by "REW" (and "LEW"), signifying the right edge of water (and left edge of water).

    2. Data entries begin at the water's edge, REW, showing distance from the initial point; and end at the water's edge, LEW, showing distance from the initial point.

    3. Two lines are allowed for data pertinent to each observation. In some cases, only one of these is used.

    4. Times are noted at 15 minute intervals during the measurement.

    5. Discharge data is reported to three significant figures, except for values less than 1, where hundreths are sufficient.

    6. For each of the last four data entries the observed velocity has been adjusted by the angle coefficient. This corrects for cases where the direction of flow is not perpendicular to the cross-section. The coefficient is obtained as follows:

Figure 4 —Computation notes of a current-meter measurement by the midsection method.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES DIVISION

DISCHARGE MEASUREMENT NOTES

Meas. No. ....

Comp. by ....

Checked by ....

Sta. No. ....

Date ...., 19...... Party ....

Width .... Area .... Vel. .... G. H. .... Disch. ....

Method .... No. secs. .... G. H. change .... in .... hrs. Susp. ....

Method coef. .... Hor. angle coef. .... Susp. coef. .... Meter No. ....

GAGE READINGS				
Time		Recorder	Inside	Outside
....				
....				
....				
....				
....				
....				
....				
....				
Weighted M. G. H.				
G. H. correction				
Correct M. G. H.				

Date rated .... Used rating

for rod .... susp. Meter .... ft.

above bottom of wt. Tags checked ....

Spin before meas. .... after ....

Meas. plots ....% diff. from .... rating

Wading, cable, ice, boat, upstr., downstr., side

bridge .... feet, mile, above, below

gage, and ....

Check-bar, chain found ....

changed to .... at ....

Correct ....

Levels obtained ....

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following

conditions: Cross section ....

Flow .... Weather ....

Other .... Air ....°F@ ....

Gage .... Water ....°F@ ....

.... Record removed .... Intake flushed ....

Observer ....

....

Control ....

Remarks ....

....

G. H. of zero flow .... ft.

Figure 3

Angle coef. point	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	VELOCITY		Adjusted for hor. angle or	Area	Discharge
							At point	Mean in vertical			

a. Hold the data sheet horizontally with the point of origin (0) (which is on the left edge) over the tag line, bridge rail, or other feature parallel to the cross-section, as shown in Figure 5.
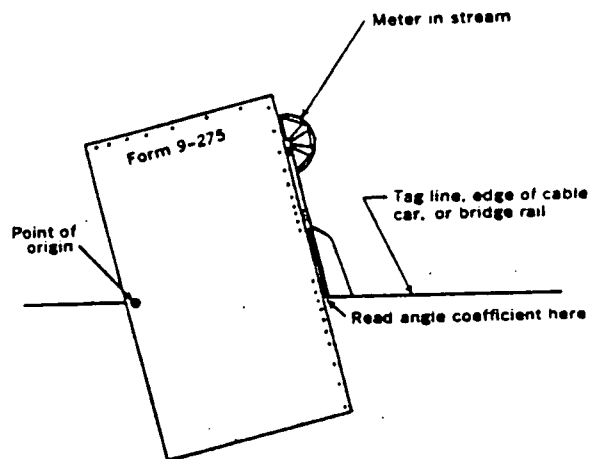
Figure 5 —Measurement of horizontal angles.

b. The tag line will intersect the value of the cosine of the angle α on the top, bottom, or edge of the data sheet.

c. Multiply the measured velocity by the cosine of the angle to determine the velocity component normal to the measuring section.

IV. Mean gage height of discharge measurements

A. The mean gage height represents the mean height of the stream during the period the measurement was. made, and is referred to the datum of the gaging station.

B. An accurate determination of the mean gage height is as important as an accurate measurement of the discharge, since it is used to establish the stage-discharge relation.

C. When the change in stage during a measurement is 0.1 foot or less, the mean can be obtained by inspection. When greater stage changes occur, the mean is obtained by weighting the gage-height readings.

D. To obtain an accurate mean gage height

1. Read the gage before and after the discharge measurement

2. Read the recorder chart at breaks in the slope of the gage-height graph during the measurement.

a. At nonrecording stations the gage must be read once or twice during the measurement.

3. Plot time vs. observed gage heights (Figure 6)

	Dist. from initial point ①	Width ②	Depth ③	Rev. ④	Rev. dur. time ⑤	Time in sec ⑥	VELOCITY		Adjusted for hor. angle of	Area	Discharge
							At point	Mean in vertical			
	Time	GHt.	Ave. GHt.		Q		①x④				
	1330	1.94	1.92		16.10		30.91				
	1345	1.90	1.70		24.31		41.33				
	1400	1.49	1.67		20.97		35.05				
	1415	1.85	1.88		14.97		28.14				
	1430	1.92									
			Total Q =		76.37	Total 135.43					
⊙	M.G.H =	$\dfrac{\text{Total } ① x ④}{\text{Total } Q}$ =			$\dfrac{135.43}{76.37}$ = 1.77						
	Time	G Ht.	Ave. GHt.	Ave. GHt. minus base	Q	③x⑤					
	1330	1.94	1.92	.25	16.10	4.02					
	1345	1.90	1.70	.03	24.31	.73					
	1400	1.49	1.67	.00	20.97	.00					
	1415	1.85	1.88	.21	14.97	3.14					
	1430	1.92									
	Base	1.67			Total Q = 76.37	Total 7.89					
	MGH = Base +	$\dfrac{\text{Total } ③ x ⑤}{\text{Total } Q}$	=	1.67 + $\dfrac{7.89}{76.37}$ =	1.67 + .10 = 1.77						

Figure 6 —Computation of weighted mean gage height.

4. Determine mean gage heights and corresponding measured partial discharges during periods of constant slope of the graph.

5. Compute mean gage height of the measurement. The formula is:

$$H=\frac{q_1h_1+q_2h_2+q_3h_3\ldots\ldots\ldots+q_nh_n}{Q}$$

in which

$H=$ mean gage height, in feet,

$Q=$ total discharge measured, in cubic feet per second $=$
$q_1+q_2+q_3\ldots\ldots+q_n,$

$q_1, q_2, q_3, \ldots q_n=$ amount of discharged measured during time interval 1, 2, 3, ... n, in cubic feet per second,

$h_1, h_2, h_3, \ldots h_n=$ average gage height during time interval 1, 2, 3, ... n, in feet.

6. The computations are shown in Figure 6, using data from the measurement shown in Figure 4..

   a. The upper computation has been done using the given formula.
   b. The lower computation uses a shortcut method which eliminates the multiplication of large numbers.

     1) Compute average gage height for each time interval.
     2) Choose a "base" gage height (usually the lowest average gage height).
     3) Use the differences between the "base" gage height and the average gage heights to weight the discharges
     4) Compute the mean difference and add the "base" gage height for the measurement.

V. Channel storage

   A. When a measurement is made at some distance from a gaging station during a change in stage, the discharge passing the gage during the measurement will not be the same as the discharge at the measuring section because of the effects of channel storage between the two locations.

   B. The method of adjusting the measured discharge for channel storage is given in the reference.

Reference: 1. Buchanan, T.J. and Somers, W.P. Techniques of Water-Resources Investigations of the USGS. Discharge Measurements at Gaging Stations. Book 3, Chapter A8, Applications of Hydraulics. 1969. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. $0.70.

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CURRENT METER MEASUREMENT PROCEDURE

A. Select a reach of stream having the following characteristics:

1. A straight reach with the threads of velocity parallel to each other.

2. Stable streambed free of large rocks, weeds, and protruding ob-
    structions such as piers, which would create turbulence.

3. A flat streambed profile to eliminate vertical components of
    velocity.

B. Usually all of these conditions will not be satisfied. Select the best
    possible reach using these criteria, then select a cross-section.

1. Ideal section is perpendicular to the direction of flow, bed and
    banks uniform, minimum V greater than 0.5 fps and depth adequate
    for use of 2 point method.

C. After selecting sections, determine width of stream.

1. String a tag line or measuring tape at right angles to the
    direction of flow .

D. Determine spacing of the verticals.

1. Generally, use about 25-30 partial sections.

    a. With smooth cross-section and good velocity distribution,
        fewer sections may be used.

2. Space the sections so that any one section has no more than 10%
    (ideally 5%) of the total flow passing through it.

3. Equal widths of partial sections are not recommended unless dis-
    charge is well distributed.

    a. Make the section width less as depths and velocities become
        greater.

E. For each discharge measurement, record the following:

1. Name of stream and exact location of site

2. Date, party, type meter suspension, and meter number

3. Time measurement began and ended

4. Bank of stream that was starting point (LEW or REW i.e., left
    edge of water or right edge of water, when facing down stream)

5. Any other pertinent information

F. Measurement Procedure:

1. Enter on the data form the distance from the initial point
    to the edge of the water. Measure and record water depth
    at edge of stream.

2. Enter distance from initial point to first vertical, and water
    depth at first vertical.

3. Determine method of velocity measurement. Normally, the two-point
    or the 0.6-depth method is used.

4. Compute the setting of the meter for the method to be used.

5. Record the meter position (0.8, 0.6, 0.2 . . .).

6. Place the meter at proper depth and permit it to become adjusted
    to the current before starting the observation (a few seconds for
    velocities over 1 fps, longer for lower velocities).

7. Read time to nearest second.

8. Record number of revolutions and time interval.

9. Repeat steps 2-8 at each vertical. Record for each the distance
    from initial point, depth, meter-position depth, revolutions,
    and time intervals.

USING THE TOP-SETTING ROD

1. Read water depth at vertical on the graduated hexagonal rod.

   Single grooves are 0.1 ft. marks
   Double grooves are 0.5 ft. marks
   Triple grooves are 1.0 ft. marks

2. The meter is set at the proper depth for taking the velocity measurement by adjusting the height of the setting rod (the round rod).

   a. To set meter at 0.6 depth, adjust setting rod to read so that foot mark (on rod) is opposite decimal mark (on handle) for observed depth.

      Example: 1a) water depth = 2 ft.
                     Set "2" on setting rod opposite "0" on scale.

                2a) Water depth = 2.6 ft.
                     Set "2" on setting rod opposite "6" on scale.
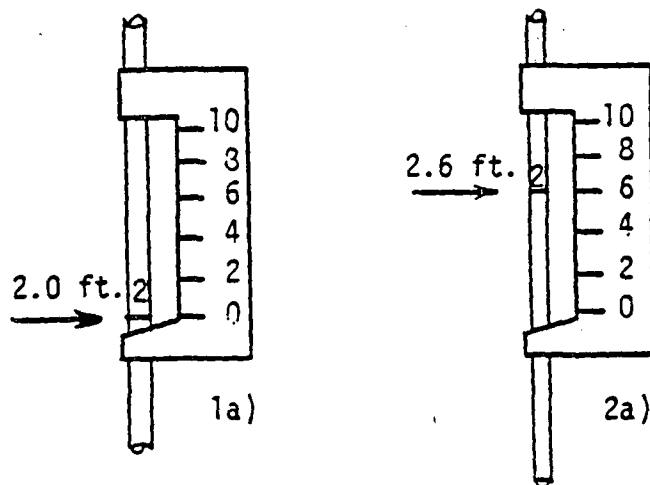
   b. To set meter at 0.2 depth, multiply water depth by 2 and set this value as above.

   c. To set meter at 0.8 depth, divide meter depth by 2 and set this value as above.

3. When setting the meter, hold the setting rod, so that the meter will not drop suddenly and hit the baseplate.

WADING MEASUREMENTS

A wading measurement is preferred, if conditions permit. Its advantage
is that it is usually possible to select the best of several available
cross-sections for the measurement.

Use the type AA or pygmy meter in accordance with the following table:

Table 2.—Current-meter and velocity-measurement method
for various depths

Depth (feet)	Meter	Velocity method
2.5 and above	Type AA (or Type A).	0.2 and 0.8
1.5–2.5	do	.6
.3–1.5	Pygmy [1]	.6

[1] Used when velocities are less than 2.5 fps.

Use the same meter for the entire measurement. Do not change from the AA
to the pygmy for a few depths less than 1.5 feet or vice versa. Use the
type AA meter in depths as shallow as 0.5 feet, even though its use is not
recommended in depths less than 1.0 foot because the registration of the
meter is affected. Do not use these meters in velocities less than 0.2 fps
unless absolutely necessary.

When natural conditions for measuring are in the range considered undependable,
modify the measuring cross section, if practical, to provide acceptable con-
ditions. Often it is possible to build dikes to cut off dead water and
shallow flows in a cross section, or to improve the cross section by removing
the rocks and debris within the section and from the reach of stream im-
mediately upstream from it. After modifying a cross section, allow the
flow to stabilize before starting the discharge measurement.

Stand in a position that least affects the velocity of the water passing
the current meter. This position is usually obtained by facing the bank,
with the water flowing against the side of the leg. Holding the wading
rod at the tag line, stand from 1 to 3 inches downstream from the tag line
and 18 inches or more from the wading rod. Avoid standing in the water if
feet and legs would occupy a considerable percentage of the cross section
of a narrow stream. In small streams where the width permits, stand on a
plank or other support rather than in the water.

Keep the wading rod in a vertical position and the meter parallel
to the direction of flow while observing the velocity. If the flow is
not at right angles to the tag line, measure the angle coefficient
carefully.

Meter No. _____   Stream _____

DISCHARGE MEASUREMENT NOTES

Date _____, 19___   Party _____
Time _____   Site _____

Dist. from Initial Point	Width (Ft.)	Depth (Ft.)	Depth of Obs.	Rev-olu-tions	Time (Sec.)	Velocity-Ft/Sec		Area (Sq. Ft.)	Dis-charge (cfs)
						At Point	Mean in Verti-cal		

161.1 (10/79)
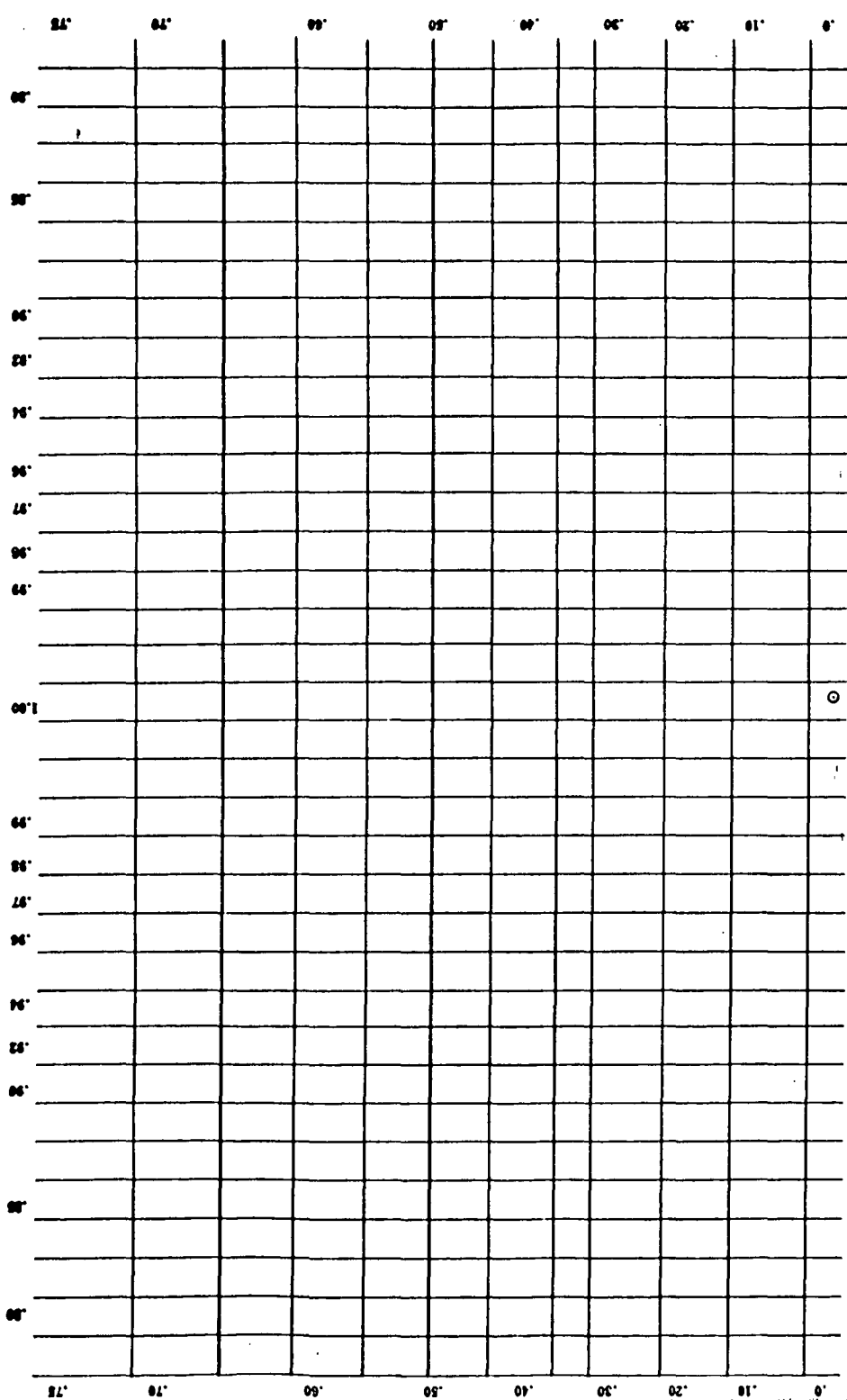
Meas. No. . . . .

Comp. by . . . .

Checked by . . . . .

. . . .

Date . . . ., 19 . . . . . . Party . . . .

Width . . . . Area . . . . Vel. . . . . G. H. . . . . Disch. . . . .

Method . . . . . No. secs. . . . . . G. H. change . . . . . . in . . . . . hrs. Susp. . . . . . .

Method coef. . . . . . . Hor. angle coef. . . . . . Susp. coef. . . . . . Meter No. . . . .

Type of meter . . . . Date rated . . . . Tag checked . . . .

Meter . . . . ft..above bottom of wt. Spin before meas. . . . . after . . . .

Meas. plots . . . . . % diff. from . . . . . rating. Levels obtained . . . .

GAGE READINGS					WATER QUALITY MEASUREMENTS
Time		Inside	ADR	Graphic	Outside
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	No . . . . . . Yes . . . . . . Time . . . . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	Samples Collected
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	No . . . . . . Yes . . . . . . Time . . . . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	Method Used
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	EDI . . . . . EWI . . . . . Other . . . . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	SEDIMENT SAMPLES
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	No . . . . . . Yes . . . . . . Time . . . . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	Method Used
						EDI . . . . . EWI . . . . . Other . . . . . .
Weighted M.G.H.	. . . .	. . . .	. . . .	. . . .	. . . .	BIOLOGICAL SAMPLES
G. H. correction	. . . .	. . . .	. . . .	. . . .	. . . .	Yes . . . . Time . . . .
Correct M.G.H.	. . . .	. . . .	. . . .	. . . .	. . . .	No . . . . Type . . . .

Check bar. chain found . . . . changed to . . . . at . . . .

Wading, cable, ice, boat, upstr., downstr., side bridge . . . . . feet, mile, above, below gage.

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%); based on the following cond:

Flow . . . .

Cross section . . . .

Control . . . .

Gage operating . . . . Weather . . . .

Intake/Orifice cleaned . . . . . . Air . . . . . . °C@ . . . . . Water . . . . . . °C@ . . . . . .

Record removed . . . . Extreme Indicator: Max. . . . . Min. . . . .

Manometer N$_2$ Pressure Tank . . . . Feed . . . . Bbl rate . . . . per min.

CSG checked . . . . Stick reading . . . .

Observer . . . .

HWM . . . . outside, in well

Remarks . . . .

. . . .

. . . .

G.H. of zero flow . . . . ft. Sheet No. . . . . of . . . . sheets

STREAM DISCHARGE MEASUREMENTS
CURRENT METERS - DESCRIPTIONS

I. Introduction

   A. Current meters are the most commonly used type of instruments when measuring flows in streams or other water bodies.

   B. Used to determine the velocity of flow at a point, based on a known relationship between the water velocity and the rate of rotation of the meter's rotor.

   C. Rate of rotor rotation is measured by opening and closing an electrical curcuit through the meter.

      1. Closing the circuit produces a flow of current which can be used to produce an audible click in a headphone or loud speaker, or activate a counting device.

      2. Knowing the number of times the circuit is closed during a revolution of the rotor, the rate of rotor rotation is easily determined.

II. General classification of current meters: Those with vertical-axis rotors (VA) and those having horizontal-axis rotors (HA). Comparative characteristics are:

   A. Vertical-axis rotor with cups or vanes (Price)

      1. Operates in lower velocities than do HA meters

      2. Bearings well-protected from silty water

      3. Rotor repairable in field without adversely affecting the rating

      4. Single rotor serves for the entire range of velocities

   B. Horizontal-axis rotor with vanes (Ott, Neyrpic, Haskell, Hoff)

      1. Rotor produces less disturbance of flow

      2. Rotor less likely to be entangled with debris than VA rotor

      3. Bearing friction less than for a VA rotor

   C. Either type of meter, when carefully designed and constructed, and when used under favorable conditions, will accurately measure the velocity of flowing water.

   D. HA meters are used extensively in Europe, but rarely in the U.S.

1. Ott meter is a precision instrument but not as durable as the Price meter under extreme conditions

2. Haskell meter has been used by the Corps of Engineers in streams that are deep, swift, and clear

3. Hoff meter has been used by the Geological Survey, the Department of Agriculture, and others, especially for measuring pipe flow. It is suited to measurement of low velocities, but not for rugged use.

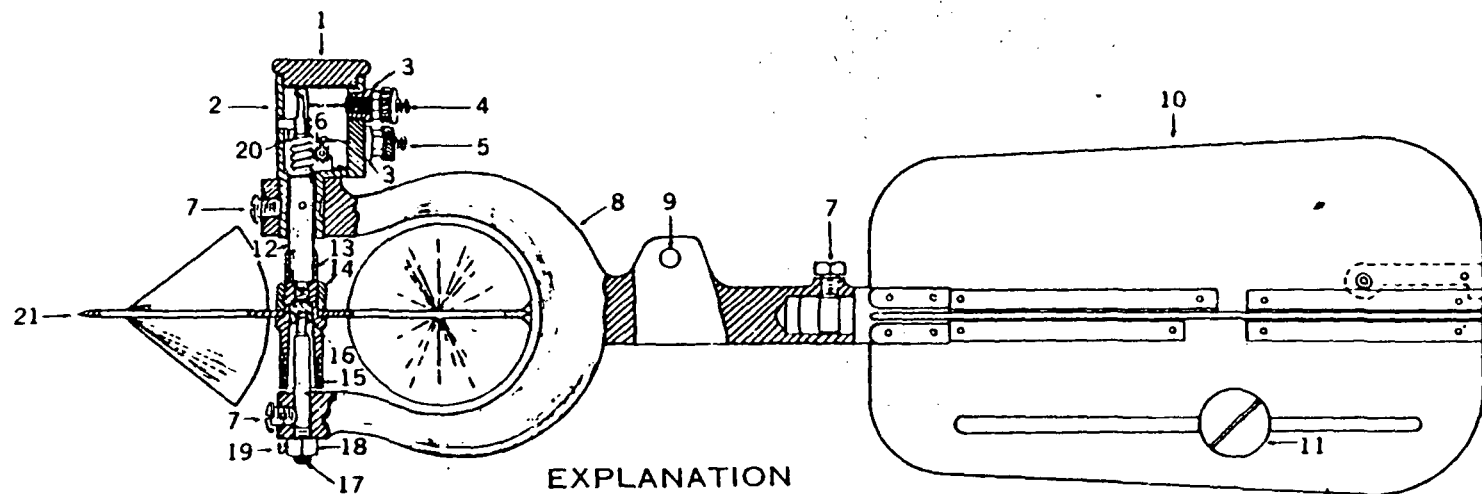III. Price meter, type AA (Figure 1), standard use

A. Most common type of VA meter

B. Rotor 5 inches in diameter, 2 inches high, with six cone-shaped cups mounted on a stainless steel shaft

C. Pivot bearing supports rotor shaft

D. Contact chamber houses upper part of shaft and an eccentric contact that wipes a bead of solder on a slender bronze wire (cat's whisker) attached to the binding post

E. A separate reduction gear (pentagear), wire, and binding post provide a contact each time the rotor makes five revolutions

F. A tail piece keeps the meter pointed into the current

G. Accurately measures velocities from 0.1 ft/sec to more than 20 ft/sec

H. Is easily repaired, can be quickly taken apart for cleaning and oiling, and quickly reassembled without change in rating

IV. Price meter, type AA, low velocity

A. No pentagear (reduces friction)

B. Shaft has two eccentrics making two contacts per revolution

C. Normally rated from 0.2 - 2.5 fps

D. Recommended when mean velocity at a cross-section is less than 1 fps
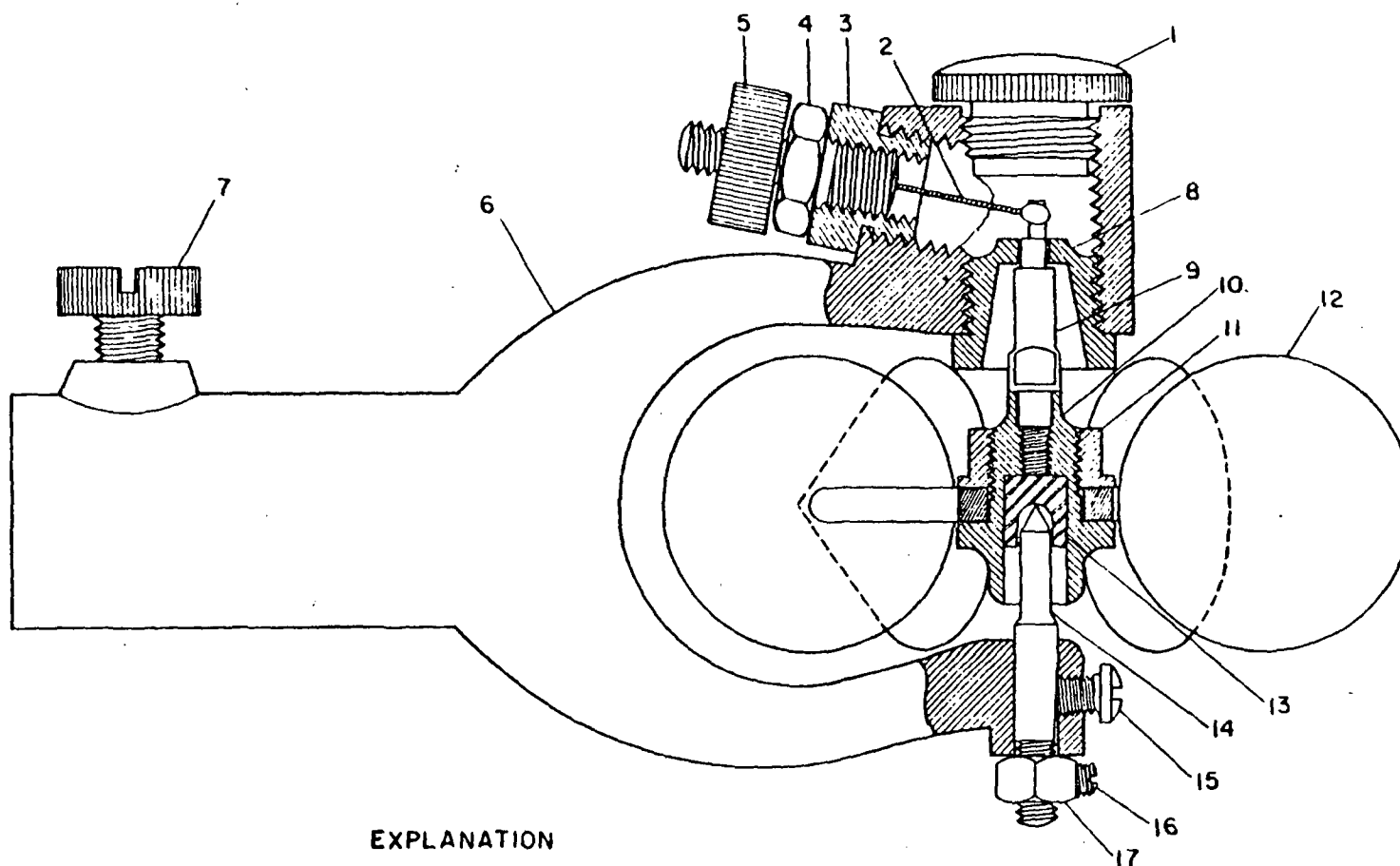
V. Price pygmy meter (Figure 2)

A. For use in shallow depths

B. Scaled 2/5 as large as standard meter

C. No tailpiece or pentagear

EXPLANATION

1	Cap for contact chamber	8	Yoke	16	Pivot bearing	
2	Contact chamber	9	Hole for hanger screw	17	Pivot	
3	Insulating bushing for contact binding post	10	Tailpiece	18	Pivot adjusting nut	
		11	Balance weight	19	Keeper screw for pivot adjusting nut	
4	Single-contact binding post	12	Shaft			
5	Penta-contact binding post	13	Bucket-wheel hub	20	Bearing lug	
6	Penta gear	14	Bucket-wheel hub nut	21	Bucket wheel	
7	Set screws	15	Raising nut			

Figure 1 - Assembly diagram of type-AA
Price current meter

3

EXPLANATION

1. Cap for contact chamber
2. Binding-post beaded wire
3. Binding-post insulating bushing
4. Binding-post body
5. Binding-post nut
6. Yoke
7. Yoke set screw
8. Upper bearing
9. Shaft

10. Bucket-wheel hub
11. Bucket-wheel hub nut
12. Bucket wheel
13. Pivot bearing
14. Pivot
15. Pivot set screw
16. Pivot-adjusting nut keeper screw
17. Pivot-adjusting nut

Figure 2 —Assembly diagram of pygmy current meter.

    D. Contact chamber an integral part of yoke

    E. One contact per revolution

    F. Used only for rod suspension

VI. Four-vane VA meter (Figure 3)

    A. For measurements under ice cover

        1. Vanes less likely to fill with slush ice

        2. Much smaller hole required to pass through ice

    B. One yoke is made to be suspended at the end of a rod and will fit holes made by an ice drill

    C. Another yoke made for regular suspensions

    D. Disadvantage of not responding as well as the Price type AA meter at velocities below 0.5 fps

VII. Price meter with magnetic switch

    A. Contact chamber which contains

        1. A magnetic switch which is

        2. Glass enclosed in a hydrogen atmosphere, and

        3. Hermetically sealed

    B. Switch is operated by a small permanent magnet fastened to the shaft

    C. Switch closes when magnet is aligned with it and then opens when magnet moves away

    D. An automatic counter is used. If a headphone is used, arcing can weld the contacts.

VIII. Direct reading meter

    A. Consists of two main parts

        1. Sensing unit (the meter proper)

        2. Indicating unit

    B. Rotor housing contains a six pole permanent magnet and hermetically sealed, magnetically operated reed switch, operating as in VII above

SIDE VIEW

TOP VIEW
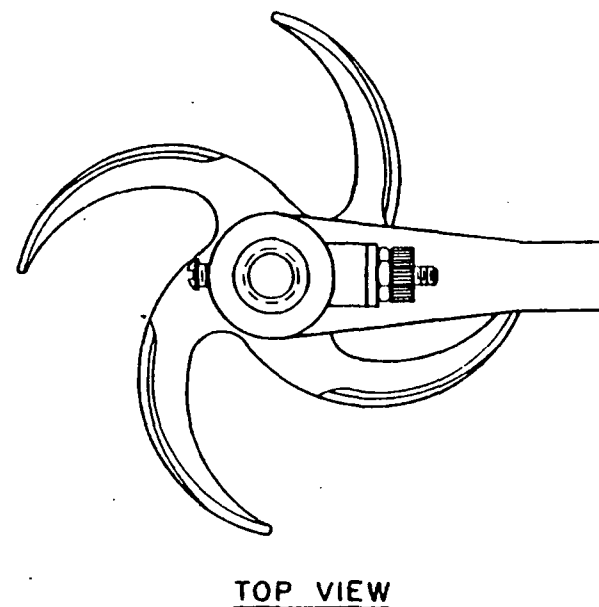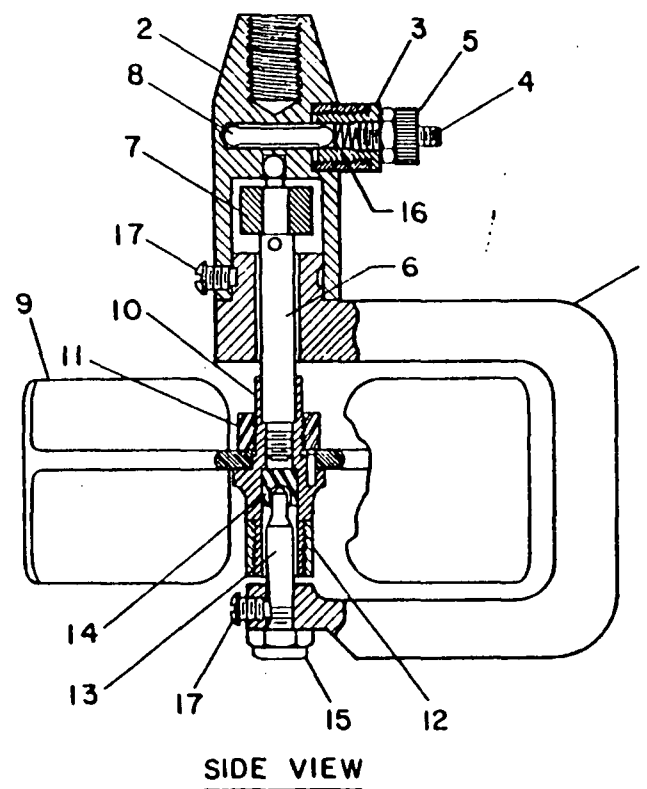
EXPLANATION

1 . Yoke	10 . Vane hub
2 . Contact chamber	11 . Vane hub nut
3 . Binding-post insulating bushing	12 . Raising nut
4 . Binding post	13 . Pivot
5 . Binding-post nut	14 . Pivot bearing
6 . Shaft	15 . Pivot-adjusting nut
7 . Magnet	16 . Compression-spring
8 . Glass switch	assembly
9 . Vane	17 . Set screw

Figure 3 — Assembly diagram of ice meter.

C. Indicating unit reads directly in velocity units (ft/sec and meters/sec).
A "high-low" scale selector switch is provided. Overall range is 0-25
ft/sec. An "Indicate-Record" switch is also provided if it is desired
to use a chart recorder for a permanent record.

References: 1. Buchanan, T.J. and Somers, W.P., Techniques of Water Re-
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May 15, 1979

STREAM DISCHARGE MEASUREMENTS
VERTICAL AXIS CURRENT METERS - CALIBRATION AND MAINTENANCE

I. Introduction

    A. The current meter is a precision instrument, but it must be properly used and maintained if it is to produce accurate data.

        1. Significant errors can result from improper care and use of the instrument.

    B. Standard operating procedures relative to the meter must include

        1. Routine servicing

        2. Routine inspection for minor damage

        3. Proper lubrication

II. Disassembly of small Price meter - precautions to be observed

    A. In removing contact chamber from yoke, care should be exercised so that the pentagear and shaft are not damaged.

    B. The bucket-raising nut (14, Figure 1) should be loosened before un-screwing the contact-chamber cap. When the nut is tightened, the upper end of the shaft bears forcibly on the cap, and turning the cap under this condition can result in a bent shaft.

    C. When raising the bucket-wheel and hub assembly by means of the raising nut, hold the bucket wheel stationary and turn the raising nut by hand. If the nut is held stationary and the bucket-wheel spun, the shaft may be bent, or the yoke may be sprung.

III. Assembly of the small Price meter (Refer to Figure 1)

    A. Assemble tailpiece vanes, insert into yoke, and tighten tailpiece set screw.

    B. Place bucket wheel (21) onto the bucket-wheel hub (13) with side marked "S" upward and with the dowel pin on the hub fitting the notch on the bucket-wheel frame.

    C. Place the bucket-wheel assembly within the arms of the yoke (8) and pass the shaft (12) through the hole in the upper arm of the yoke. Screw the shaft directly into the bucket wheel hub (13), then insert a pin into the hole in the shaft and tighten the shaft in the hub.
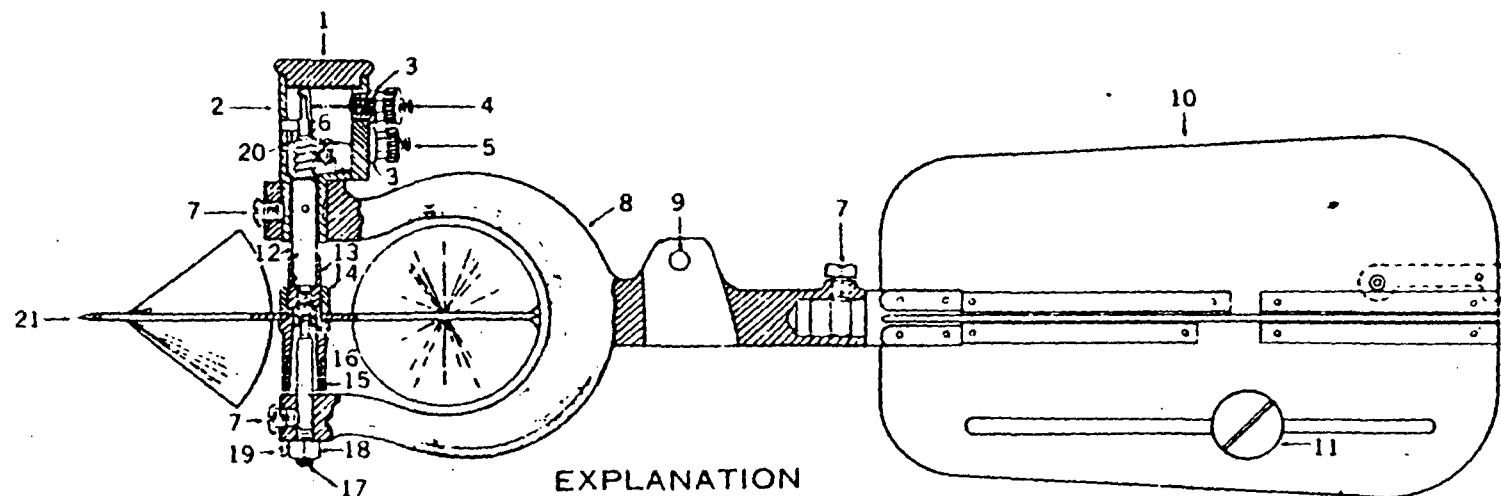
EXPLANATION

1	Cap for contact chamber	8	Yoke	16	Pivot bearing
2	Contact chamber	9	Hole for hanger screw	17	Pivot
3	Insulating bushing for contact binding post	10	Tailpiece	18	Pivot adjusting nut
4	Single-contact binding post	11	Balance weight	19	Keeper screw for pivot adjusting nut
5	Penta-contact binding post	12	Shaft	20	Bearing lug
6	Penta gear	13	Bucket-wheel hub	21	Bucket wheel
7	Set screws	14	Bucket-wheel hub nut		
		15	Raising nut		

Figure 1 - Assembly diagram of type-AA
Price current meter

D. Loosen the pentagear (6) in the contact chamber (2) by a <u>single turn of the small screw that passes through the adjusting slot of the gear pad. <u>Do not remove this screw completely as it is difficult to replace.</u>

E. Slip the contact chamber, with cap (1) removed, over the upper end of the shaft and into the hole in the upper limb of the yoke. Exercise great care so as not to damage threaded shaft or the pentagear.

F. Aline contact chamber so that center line of yoke bisects the angle formed by the two contact binding posts. Some meters have grooved marks on front of contact chamber and top of upper arm of yoke. Making these marks coincide assures proper alignment.

G. Tighten the yoke set screw (7).

H. Screw cap onto contact chamber.

I. Invert meter, place a drop of oil in the lower bearing (16) and on the pivot (17).

J. Insert the pivot through the hole in the lower arm of the yoke.

K. Adjust the pivot to allow a vertical play of 0.008 inch (Table 1)

Table 1. Adjustment of pivot

Sequence	Operation
1.....	Make sure that the meter has been properly oiled' then hold meter in inverted position with pivot uppermost.
2.....	Release keeper screw (19) for pivot adjusting nut (18) and unscrew the nut a few turns.
3.....	Release set screw (7) and advance pivot until all vertical play of the hub assembly is eliminated.
4.....	Tighten set screw (7) temporarily and advance pivot adjusting nut (18) until it touches the yoke.
5.....	Release set screw (7) (not too far because the pivot should not revolve) and advance the pivot adjusting nut one-fourth turn. Then tighten keeper screw (19).
6.....	Push the pivot inward as far as it will go and tighten set screw (7).

L. Return meter to upright position. Remove cap from contact chamber. Adjust pentagear to mesh properly with threads on shaft. Tighten small (unnumbered) screw which holds pentagear assembly.

M. Spin bucket wheel rapidly. Be sure there is freedom of action between penta gear and shaft threads.

N. Apply oil to pentagear and to the three bearing surfaces (one drop on the vertical shaft and two on the horizontal shaft that supports the gear).

O. Adjust contact wires to touch edge of eccentrics very lightly. Replace contact chamber cap and listen with headset for sharp click.

P. Place assembled meter on a solid surface with the shaft vertical and make a spin test (see paragraph VI-G below).

Q. If meter will not be used immediately, raise pivot bearing off pivot by means of the bucket-raising nut.

IV. Disassembly and assembly of Pygmy meter (Figure 2)

A. The meter is constructed so that the bucket-wheel and hub assembly can be removed from the yoke as a unit for convenience in cleaning and oiling.

B. To remove the assembly

1. Remove the cap (1)

2. Release the set screw holding the pivot in the yoke (15)

3. Remove the pivot

4. Tighten the set screw (15) into the yoke to avoid difficulties in removing the bucket wheel

5. Lower bucket wheel to lowest position in the yoke and carefully slide it forward and outward.

6. If assembly does not come out freely, return to original position and rotate it one-sixth of a turn. Repeat until successful.

7. Never apply force in removing bucket-wheel-&-hub assembly because shaft and eccentric may be bent.

C. To replace the assembly

1. Pivot should be removed, set-screw tightened, cap removed, and yoke and shaft held upside down.

2. Direct upper end of shaft into hole of upper bearing.

EXPLANATION

1. Cap for contact chamber
2. Binding-post beaded wire
3. Binding-post insulating bushing
4. Binding-post body
5. Binding-post nut
6. Yoke
7. Yoke set screw
8. Upper bearing
9. Shaft

10. Bucket-wheel hub
11. Bucket-wheel hub nut
12. Bucket wheel
13. Pivot bearing
14. Pivot
15. Pivot set screw
16. Pivot-adjusting nut keeper screw
17. Pivot-adjusting nut

Figure 2 —Assembly diagram of pygmy current meter.

3. Carefully adjust bucket wheel into position within the arms of the yoke. <u>Do not use force</u>.

4. If unsuccessful, remove it, turn it one-sixth of a revolution, and repeat until properly positioned.

5. Unscrew set-screw until pivot can be inserted.

6. Insert pivot.

7. Tighten set-screw and turn yoke rightside up.

8. Replace cap.

V. Routine oiling and cleaning of current meters

   A. At end of each day's use the meter should be throughly cleaned and oiled.

      1. Pivot and pivot bearing need special attention as they are subject to rusting. Desirable to dry these parts before oiling.

   B. Equipment required

      1. Screwdrivers of proper size

      2. Large soft cloth, water absorbent

      3. Cotton-tipped swabs for cleaning bearing surfaces

      4. Instrument oil and applicator to apply a drop in hard-to-reach places

   C. Disassemble meter and clean parts as follows

      1. Pivot bearing

         a. Clean and dry air pocket and pivot bearing (cotton-tipped swab)
         b. Inspect pivot bearing

      2. Pivot hole in yoke

         a. Swab with cotton-tipped swab

      3. Shaft

         a. Clean and dry - particularly the acme threads

      4. Pivot

         a. Wipe until throughly dry

5. Contact chamber

    a. Remove cap and shake out water. Clean occasionally with hot water flow from tap. Remove gummed oil (gun powder solvent can be successfully used)
    b. Wipe interior
    c. Swab hole in bearing lug by inserting cotton-tipped swab through stem of chamber. Cleaning from top may cause bending and breakage of contact wires.

D. Oil parts as follows

1. Shaft, apply a film of oil to

    a. Acme threads (liberally)
    b. Area that enters the bearing lug
    c. Uppermost end of shaft

2. Pivot bearing

    a. Apply thin oil film over all exposed parts

3. Pivot hole in yoke

    a. Apply a drop of oil to sides of hole

4. Pivot

    a. Apply thin film of oil

VI. Inspection and repair

Before and after each discharge measurement the meter should be checked as follows. All meter parts are manufactured to be interchangeable without affecting the calibration, so that replacement of any part can be made in the field.

A. Check rotor and shaft alignment

1. Eccentricity in bucket wheel and hub assembly can be readily detected as follows

    a. Spin bucket wheel slowly
    b. Watch metal frame to which cups are fastened

2. If eccentricity is observed, either the wheel or the shaft is bent

3. Remove cap and observe the movement of the shaft inside the contact chamber

      a. If eccentricity is noted, remove shaft from assembly and roll on clean, flat surface

      b. If bent, replace

   4. If fault is in bucket wheel, replace rotor with a new one

B. Damaged cups - bucket wheel and cups have more influence on meter rating than any other component

   1. Examine cups closely - any small distortion will change rating

   2. Attempt repair only for the most minor dents, where cups can be straightened to "like new"

   3. Otherwise replace bucket wheel with new one

C. Damaged tailpiece - may be straightened if damage not too serious, otherwise replace

D. Contact chamber - Examine for

   1. Proper meshing of pentagear with acme thread

   2. Proper adjustment of contact wires

   3. Excessive wear of upper bearing

E. Pivot and bearings

   1. Examine pivot with magnifying glass to see if point is fractured, rough, or worn flat at apex

   2. Point of new pivot is rounded to approximately 0.005". Wear resulting in a radius of more than 0.010" is excessive.

   3. Examine pivot bearing carefully for possible fracture, pits, or roughness. If any of these are noted, replace entire hub assembly.

F. Lubrication

   1. Inspect all bearing surfaces to see they have thin coating of instrument oil

   2. Bearing surfaces

      a. Pivot and pivot bearing
      b. Pentagear-acme threads
      c. Cylindrical bearing of small shaft of pentagear
      d. Thrust bearing between shaft and cap

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G. Spin tests

    1. Easy method of determining condition of bearings

    2. Place meter so shaft is in vertical position

        a. Protect from air currents

    3. Give bucket wheel quick turn

        a. Normal spin times - AA meter, 1 1/2 - 4 minutes
                               Pygmy, 1/2 - 1 1/2 minutes

    4. Observe motion of bucket wheels as they cease to rotate - they should gradually slow to a stop

    5. If bucket wheel comes to an abrupt stop, determine cause and correct

        a. Lack of oil
        b. Maladjustment of pentagear
        c. Misalignment of yoke

VII. Calibration

A. The theoretical relation between flow velocity and rotor speed is

$V = KN$

where

V = flow velocity
N = rotor speed (rotations/unit time)
K = a proportionality constant

B. In practice this simple relationship does not exist and the relation between V and N must be determined empirically.

C. The establishment of this relation (rating the meter) is done by ~~the Bureau of Standards for~~ the Geological Survey.

    1. Arrangements can be made with the Bureau to have a meter rated. The Hydraulic Laboratory of the Rensselaer Polytechnic Institute will also rate an individual meter.
       or Manufacturer (Gurley)

D. A standard rating table is furnished with each Price meter.

    1. Developed by calibrating a large number of meters that have been constructed according to Survey specifications

    2. A rating table for an individual meter is shown in Figure 3

DEPARTMENT OF INTERIOR – GEOLOGICAL SURVEY
Water Resources Division
RATING TABLE FOR TYPE M ...CURRENT METER NO. 3684 ....
SUSPENSION Rod   RATED February 16, 1962

INDEX...... 377-376
EQUATIONS. V = ... = 0.030(2.280)2.240A + 0.040 .....
Limits of Actual Rating 0.25 to 8.0 feet per sec
at Bureau of Standards, Wash., D.C. Condition of Meter New

NO. 3684

VELOCITY IN FEET PER SECOND — Revolutions

Time in Seconds	3	5	7	10	15	20	25	30	40	Time in Seconds
40	.199	.311	.424	.592	.874	1.15	1.44	1.72	2.28	40
41	.195	.304	.414	.579	.853	1.13	1.40	1.68	2.23	41
42	.191	.298	.405	.566	.834	1.10	1.37	1.64	2.17	42
43	.187	.292	.396	.553	.815	1.08	1.34	1.60	2.12	43
44	.183	.286	.388	.541	.797	1.05	1.31	1.56	2.08	44
45	.180	.280	.380	.530	.780	1.03	1.28	1.53	2.03	45
46	.177	.275	.372	.519	.764	1.01	1.25	1.50	1.99	46
47	.174	.269	.365	.509	.748	.987	1.23	1.47	1.94	47
48	.171	.264	.358	.499	.733	.968	1.20	1.44	1.91	48
49	.168	.260	.351	.489	.719	.948	1.19	1.41	1.87	49
50	.165	.255	.345	.480	.705	.930	1.15	1.38	1.83	50
51	.162	.251	.339	.471	.692	.912	1.13	1.35	1.79	51
52	.160	.246	.333	.463	.679	.895	1.11	1.33	1.76	52
53	.157	.242	.327	.455	.667	.879	1.09	1.30	1.73	53
54	.155	.238	.322	.447	.655	.863	1.07	1.28	1.70	54
55	.153	.235	.316	.439	.644	.848	1.05	1.26	1.67	55
56	.151	.231	.311	.432	.633	.834	1.03	1.24	1.64	56
57	.148	.227	.306	.425	.622	.819	1.02	1.21	1.61	57
58	.146	.224	.302	.418	.612	.806	1.00	1.19	1.58	58
59	.144	.221	.297	.411	.602	.793	.983	1.17	1.56	59
60	.142	.218	.292	.405	.592	.780	.968	1.15	1.53	60
61	.141	.214	.288	.399	.583	.769	.952	1.14	1.51	61
62	.139	.211	.284	.393	.574	.756	.937	1.12	1.48	62
63	.137	.209	.280	.387	.566	.744	.923	1.10	1.46	63
64	.135	.206	.276	.382	.557	.733	.909	1.08	1.44	64
65	.134	.203	.272	.376	.549	.722	.895	1.07	1.41	65
66	.132	.200	.269	.371	.541	.712	.882	1.05	1.39	66
67	.131	.198	.265	.366	.534	.702	.870	1.04	1.37	67
68	.129	.195	.262	.361	.526	.692	.857	1.02	1.35	68
69	.128	.193	.258	.356	.515	.682	.845	1.01	1.33	69
70	.126	.191	.255	.351	.512	.673	.834	.994	1.32	70
	3	5	7	10	15	20	25	30	40	

VELOCITY IN FEET PER SECOND — Revolutions

Time in Seconds	50	60	80	100	150	200	250	300	350	Time in Seconds
40	2.84	3.40	4.52	5.64	8.44	11.24	14.04	16.84	19.64	40
41	2.77	3.32	4.41	5.50	8.24	10.97	13.70	16.43	19.16	41
42	2.71	3.24	4.31	5.37	8.04	10.71	13.37	16.04	18.71	42
43	2.64	3.17	4.21	5.25	7.85	10.46	13.06	15.67	18.27	43
44	2.59	3.09	4.11	5.13	7.68	10.22	12.77	15.31	17.86	44
45	2.53	3.03	4.02	5.02	7.51	10.00	12.48	14.97	17.46	45
46	2.47	2.96	3.94	4.91	7.34	9.78	12.21	14.65	17.08	46
47	2.42	2.90	3.85	4.81	7.19	9.57	11.95	14.34	16.72	47
48	2.37	2.84	3.77	4.71	7.04	9.37	11.71	14.04	16.37	48
49	2.33	2.78	3.70	4.61	6.90	9.18	11.47	13.75	16.04	49
50	2.28	2.73	3.62	4.52	6.76	9.00	11.24	13.48	15.72	50
51	2.24	2.68	3.55	4.43	6.63	8.82	11.02	13.22	15.41	51
52	2.19	2.62	3.49	4.35	6.50	8.66	10.81	12.96	15.12	52
53	2.15	2.58	3.42	4.27	6.38	8.49	10.61	12.72	14.83	53
54	2.11	2.53	3.36	4.19	6.26	8.34	10.41	12.48	14.56	54
55	2.07	2.48	3.30	4.11	6.15	8.19	10.22	12.26	14.29	55
56	2.04	2.44	3.24	4.04	6.04	8.04	10.04	12.04	14.04	56
57	2.00	2.40	3.18	3.97	5.93	7.90	9.86	11.83	13.79	57
58	1.97	2.36	3.13	3.90	5.83	7.76	9.70	11.63	13.56	58
59	1.94	2.32	3.08	3.84	5.73	7.63	9.53	11.43	13.33	59
60	1.91	2.28	3.03	3.77	5.64	7.51	9.37	11.24	13.11	60
61	1.87	2.24	2.98	3.71	5.55	7.38	9.22	11.06	12.89	61
62	1.84	2.21	2.93	3.65	5.46	7.27	9.07	10.88	12.69	62
63	1.82	2.17	2.88	3.60	5.37	7.15	8.93	10.71	12.48	63
64	1.79	2.14	2.84	3.54	5.29	7.04	8.79	10.54	12.29	64
65	1.76	2.11	2.80	3.49	5.21	6.93	8.66	10.38	12.10	65
66	1.73	2.08	2.76	3.43	5.13	6.83	8.52	10.22	11.92	66
67	1.71	2.04	2.71	3.38	5.05	6.73	8.40	10.07	11.74	67
68	1.68	2.02	2.68	3.33	4.98	6.63	8.28	9.92	11.57	68
69	1.66	1.99	2.64	3.29	4.91	6.53	8.16	9.78	11.40	69
70	1.64	1.96	2.60	3.24	4.84	6.44	8.04	9.64	11.24	70
	50	60	80	100	150	200	250	300	350	

Figure 3 —Current-meter rating table.

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a. Equations are shown in the heading for use in cases where the table must be extended.

b. Equation to left of figure in parentheses (2.28) is for velocities less than 2.28 fps., equation to the right for velocities greater than 2.28 fps.

E. For pygmy meters the rating usually used is

$V = N$

where V = velocity ft/sec

N = rotor speed, rev./sec.

for velocity < 1 ft/sec use $V = 0.969N + 0.043$

References: 1. Smoot, G.F. and Novak, C.E. Techniques of Water Resources Investigations of the USGS: Calibration and Maintenance of Vertical-Axis Type Current Meters, Book 8, Chap. B2, 1968. For sale by Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. $0.40.

2. Bulletin 700, Hydrological Instruments. Teledyne Gurley. Troy, New York 12181. 1977.

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